

beam splitter 114, the imaging lens 118, and the first detector 120 with the unaltered optical path 106. The target object 102, being the subject of imaging by the imaging system 100 and found in the flow cell cuvette 104, emits, reflects, scatters, or refracts object light 132 to be received, collected, and passed by the collection lens 108 as collected light 134 being collimated light having generally parallel light rays being focused approximately at infinity. The collected light 134 enters the amplitude beam splitter 110, which splits the collected light into two optical paths having a first transmitted light 136 and a first reflected light 138, respectively, in accordance with the beam splitter optical coating 112 on the amplitude beam splitter.

10           The first transmitted light 136 is left unaltered and passes through the amplitude beam splitter 114 in accordance with the beam splitter optical coating 116 as second transmitted first transmitted light (2T1T light) 138. The amplitude beam splitter 114 is oriented slightly by a mechanical angle 104 with respect to the y-axis such that the second reflected defocused light (2R defocused light) is oriented at an optical angle of separation 142 with respect to both the x-axis and the 2T1T light 138. The 2T1T light 138 is then focused by the imaging lens 118 as imaged 2T1T light 144, which converges to focus at 2T1T image plane 146. The first reflected light 138 reflected by the beam splitter optical coating 112 is redirected by the first reflector 124 to pass through the defocus system 126 thereby producing defocused first reflected light (defocused 1R light) 148, being decollimated light having optical power modified by the defocus system. The defocused 1R light 148 is then redirected by the second reflector 130 to pass through the amplitude beam splitter 114 to be reflected in accordance with the beam splitter optical coating 116. The 2R defocused light is brought to focus by the imaging lens 118 as imaged 2R defocused light 150, at 2R defocused image plane 152.

25           The amount of defocus introduced by the defocus system 126 results in the 2T1T image plane 146 and 2R defocused image plane 152 being spatially separated from one another along the x-axis such that their depths of focus overlap. As shown in Figure 3, the first detector 120 is positioned with respect to a first detector image plane 154 and uses this overlap of depths of focus of the 2T1T image plane 146 and the 2R defocused image

plane 152 to effectively increase the overall depth of focus of the imaging system 100 for the first detector. The imaging system 100 provides, for the first detector 120 in the first detector image plane 154, two conjugate 2T1T object planes 156 and 2R defocused object plane 158 associated with an unaltered object light 160 and a defocus object light 162, respectively, as shown in Figures 3-5. As shown in Figure 5, the 2T1T object plane 156 has a 2T1T object field depth 164 and the 2R defocused object plane 158 has a 2R defocused object field depth 166, which have a first object field depth overlap 168. In other implementations the first object field depth overlap 168 may not exist for other tailoring of the depth of focus.

Implementations include the beam splitter optical coating 112 and the beam splitter optical coating 116 being an amplitude beam splitter type with transmittance and reflectance being nominally equal. The optical component of the amplitude beam splitter 110 and the amplitude beam splitter 114 and their respective beam splitter optical coating 112 and beam splitter optical coating 116 may have the coatings bonded between two prism elements. Alternative implementations use plate or pellicle versions of the amplitude beam splitter 110 and the amplitude beam splitter 114 with their respective beam splitter optical coating 112 and beam splitter optical coating 116 being deposited on one surface. In some implementations, the first reflector 124 and the second reflector 130 are prisms, as illustrated, having total internal reflection from uncoated surfaces. Other implementations of the first reflector 124 and the second reflector 130 use reflective metallic or dielectric optical coatings deposited on surfaces including, but not limited to, a mirror surface of a plane mirror.

It is important to control intensities of the imaged 2T1T light 144 and the imaged 2R defocused light 150, so that, typically, the image intensities are substantially equal at the first detector 120. Intensity control can be achieved in a number of ways. Depending upon the relative optical path efficiencies, such as the optical efficiency of the unaltered optical path 106 versus the optical efficiency of the defocus optical path 122, it may be desirable to employ other than an equal transmittance/reflectance ratio for the beam splitter optical coating 112 or the beam splitter optical coating 116. For example, if the

additional optical elements in the defocus optical path 122 were to result in more absorption loss relative to the unaltered optical path 106, it would be beneficial to reflect more light at the beam splitter optical coating 112 and transmit less light to the unaltered optical path to balance the light intensity in the imaged 2T1T light 144 and the imaged 2R defocused light 150. Commonly available transmittance/reflectance split ratios for commercially available beamsplitter coatings include 50/50, 60/40, 40/60, 30/70, and 70/30. Other implementations using other split ratios for light intensity control are readily achievable with customized optical coatings known in the art.

In addition to the choice of beamsplitter coating, such as choice of the beam splitter optical coating 112 or the beam splitter optical coating 116, light intensity can be controlled by placement of neutral density (ND) filters in the unaltered optical path 106 or the defocus optical path 122. In some implementations reflective or absorptive type filters are used to reduce intensity in the unaltered optical path 106 or the defocus optical path 122 to match that of the other. For instance, a single filter of the appropriate density value is used in some implementations to correct the mismatch while a variable density filter component such as a stepped ND filter or linear wedge neutral density filter is used in other implementations where optical density of the coating varies linearly with position as needed. Implementations using a variable density filter take advantage of its convenient light intensity adjustment and single design approach to compensate for variation in component efficiencies in a manufacturing environment.

In alternative implementations of the imaging system 100 illustrated in Figures 6-9, a second of the imaging lens 118 is used to focus that portion of the first transmitted light 136 reflected by the beam splitter optical coating 116 of the amplitude beam splitter 114 into an imaged 2R1T light 170 on the 2R1T image plane 172. The second imaging lens 118 also focuses that portion of the defocused 1R light 148 transmitted by the beam splitter optical coating 116 of the amplitude beam splitter 114 into imaged 2T defocused light 174 onto the 2T defocused image plane 176. The 2R1T image plane 172 and the 2T defocused image plane 176 have a corresponding 2R1T object plane 178 and a 2T defocused image plane 180, respectively. The implementations also have a